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HEAT-RESISTANT AND ABRASION-RESISTANT ALUMINUM ALLOY

[TAINETSU TAIMAMOSEI ARUMINIUMU GOKIN]

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TITLE	(54):	HEAT-RESISTANT AND ABRASION-RESISTANT ALUMINUM ALLOY
FOREIGN TITLE	(54A):	Tainetsu Taimamosei Aruminiumu Gokin

SPECIFICATION

I. Title of the Invention

Heat-Resistant and Abrasion-Resistant Aluminum Alloy

II. Scope of Patent Claims

1. A heat-resistant and abrasion-resistant aluminum alloy, characterized in that it comprises 5.0 to 40 wt% of Si element, 2 to 15 wt% of Fe and Ni elements by (Fe+Ni); the ratio of Fe to Ni is Fe:Ni = 1:4 ~ 4:1; one or two kinds selected from 0.1 to 6.0 wt% of Cu and 0.1 to 8.0 wt% of Mg are comprised; and the balance substantially comprises aluminum in an aluminum alloy containing Si, Fe and Ni.

2. A heat-resistant and abrasion-resistant aluminum alloy, characterized in that it comprises 5.0 to 40 wt% of Si, 2 to 15 wt% of Fe and Ni elements by (Fe+Ni); the ratio of Fe to Ni is Fe:Ni = 1:4 ~ 4:1; it comprises one, two or more kinds selected from a set composed of 0.5 to 6.0 wt% of Cu, 0.1 to 8.0 wt% of Mg, 0.05 to 5.0 wt% of Zn, 0.05 to 5.0 wt% of Ti, 0.05 to 60 wt% of Cr, 0.05 to 3.0 wt% of Zr, 0.05 to 5.0 wt% of Co, 0.05 to 4.0 wt% of Mo,

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[1]Numbers in the margin indicate pagination in the foreign text.

0.05 to 40 wt% of W, 0.05 to 4.0 wt% of Ce; and the balance substantially comprises aluminum in an aluminum alloy containing Si, Fe and Ni.

3. The heat-resistant and abrasion-resistant aluminum alloy of Claim 1 and 2 wherein the size of metal compounds and a deposit obtained by solidification at a solidifying rate of 100°C/sec or above is less than 50 μm.

4. The heat-resistant and abrasion-resistant aluminum alloy of Claim 1 or 2 wherein an atomized powder having a particle size of 40 mesh or less or a powder of 50 μm or less in particle diameter of an primary crystal deposit is molded by hot plastic processing.

[Field of Industrial Application]

The present invention relates to an improvement on the strength of an Al-Si-Fe-Ni heat-resistant and abrasion-resistant aluminum alloy.

[Prior Art and Problem to Be Solved by the Invention]

Recently, miniaturization, lightening and high output are contrived from the necessity of materials for automobile engines, airplanes, and so on, that are energy saving and high performance;

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therewith it has been required that materials used in pistons, etc. be resistant for use under severe conditions of higher loads and higher temperatures than before. For an automobile piston requiring heat resistance and abrasion resistance, for example, Al-Si cast materials, such as AC8A and AC8B, have been used as conventional aluminum alloys for conventional pistons. However, if a large amount of Si and/or Fe, Ni, and so on are added by casting process to further improve the heat resistance and abrasion resistance, characteristics such as strength, elongation, toughness, and so on markedly deteriorate due to the segregation of elements and coarsening of primary crystals, and thus the required characteristics cannot be fully satisfied.

In recent years, development of heat-resistant and abrasion-resistant aluminum alloy materials with pore-free and uniform microcrystal grains by hot extrusion process, using a quenched aluminum alloy powder with a high Si content as a starting material, has been begun.

Although a large amount of Si and/or Fe and Ni, and so on is solid dissolved due to expansion of the solid dissolution limit based on an effect of quench solidification, almost no coarse deposit and/or segregate, as observed in a cast material, occur in an alloy prepared in this manner.

However, when a quenched powder is used, the aluminum alloy material also has the problem of grain growth caused by heating in molding for compacting, thus the method naturally has a limit. For instance, an aluminum alloy mainly containing 20 ~ 30 wt% of Si and 2 ~ 10 wt% of Fe or transition metals, such as Ni and so on, is manufactured with a heat-resistant and abrasion-resistant aluminum alloy manufactured by a quenched powder metallurgical process by hot extrusion of the rapidly solidified powder; although the heat resistance and abrasion resistance are improved, elongation and toughness are markedly reduced in the aluminum alloy thus obtained. A reason for this is a primary crystal deposit and metal compounds generated in the hot extrusion. Uses of the highly alloying aluminum alloy manufactured by the quenched powder metallurgical process are limited because of its low elongation and low toughness.

[Means for Solving the Problem]

The present invention was made to improve the toughness and elongation of highly alloying aluminum alloys composed of Al, Si, and Fe or Ni, and an object of the present invention is to increase the toughness of a conventional highly alloying heat-resistant and abrasion-resistant aluminum alloy composed mainly of three elements, Al-Si-Fe or Al-Si-Ni or the like, and to improve its strength at room temperature or high temperatures

simultaneously by containing transition metals (Fe, Ni) in the alloy at a proper ratio.

Si is an element added to the aluminum alloy and is effective for the improvement of abrasion resistance. If Si is added to Al in a large amount, it deposits as primary crystal Si grains during solidification, and the abrasion resistance increases. The size and the quantity of primary crystal Si grains greatly depends on the solidification rate of the alloy and the amount of Si; if the solidification rate is fast, the primary crystal Si grains reduce, but it becomes coarse as the Si amount increases. 40 wt% is taken as its limit. If the Si amount is more than this limit, the primary crystal Si grains become coarse, and thereby the alloy strength markedly reduces. If the amount is less than 5 wt%, the effect of improving the abrasion resistance is very small, thus the alloy is difficult to use as an abrasion-resistant material.

Fe and Ni improve the heat resistance of the aluminum alloy, and Fe has a larger effect. However, Fe gives lower elongation and toughness than Ni. An alloy having better characteristics than the original alloys Al-Si-Fe and Al-Si-Ni is obtained by replacing part of the Fe or Ni of these alloys, respectively, with either Ni or Fe. Namely, the Al-Si-Fe-Ni alloy has slightly reduced heat resistance but improved elongation as compared to

the Al-Si-Fe alloy; [the Al-Si-Fe-Ni] alloy has slightly reduced elongation but improved heat resistance as compared to Al-Si-Ni. It is particularly noteworthy that the [Al-Si-Fe-Ni] alloy has higher toughness than either Al-Si-Fe or Al-Si-Ni. The reason for it is considered as follows. It has been known that the limits of solid dissolution into Al for both Fe and Ni are as small as 0.04 wt%, however, the limits of solid dissolution are expanded by rapid solidification, and the maximum solid dissolution range is 4 ~ 12 wt% for Fe and 3 ~ 15 wt% for Ni. The supersaturated portion more than the solid dissolution limits expanded by quenching in Fe or Ni added into Al deposits as a deposit of compounds or the like, and it markedly reduces the toughness of alloy. However, the degree of supersaturation can be reduced by replacing part of Fe with Ni or part of Ni with Fe in order to produce a very fine and uniform deposit. Therefore, the toughness is greatly improved. Here, only Fe and Ni are shown,

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however, the same idea of combining is applicable with other elements, therefore the effect of improving the toughness by replacing elements can be expected. The range of the Fe:Ni ratio of this Al-Si-Fe-Ni alloy showing nearly the same toughness value as Al-Si- Ni is 1:4 ~ 4:1. The most preferable Fe:Ni ratio is 1:1. If the amount of Fe + Ni becomes more than 12 wt%, both the

toughness and elongation markedly reduce, therefore the amount of Fe + Ni is under 12 wt%. If the amount of Fe + Ni is less than 2 wt%, the effect of improving the heat resistance almost disappears, therefore the amount of Fe + Ni is more than 2 wt%.

In another set composed of Cu, Mg, Zn, Ti, Cr, Zr, Co, Mo, W, and Ce, the elements Cu, Mg, and Zn are mainly time-effect hardening elements, and they improve the strength and hardness of the alloy up to about 200°C. At low temperatures below 200°C, the abrasion resistance is also markedly improved by increasing the hardness based on the time effect. The amount of element for fully displaying these effects is 0.5 ~ 6.0 wt% for Cu, 0.1 ~ 8.0 wt% for Mg, and 0.05 ~ 0.5 wt% for Zn. Ti, Cr, Zr, Co, Mo, W, and Ce are effective for improving the heat resistance. These elements improve the heat resistance by generating stable metal compounds in the alloy; however, if the elements are added in a large amount, the quantity of metal compounds increases, and the elongation and toughness of the alloy are markedly impaired; if they are added in a small amount, the effect of improving the heat resistance is not fully displayed.

As described above, when an Al alloy, containing Si, Fe, Ni, and so on in a large amount, is manufactured by conventional melting and casting processes, the solidification rate is slow (1°C/sec or lower), therefore Si primary crystal and metal

compounds become coarse, and the material strength markedly reduces. As methods for suppressing the coarse deposit, a rapid solidification process and a hot top process are given. In the hot top process, the limit for the amount of elements is low. In the rapid solidification process, if it is quenched at a solidification rate of 100°C/sec, the maximum size of the deposit is about 50 μm in the ranges of amount for the elements shown in the present invention, and it cannot be a way to greatly lower material properties.

To obtain such a solidification rate, it can be easily achieved by making the alloy from a molten state into a powder by the atomization process. From the viewpoint of the moldability of the powder or the solidification rate, the particle size of the powder suited for use is 40 mesh or less. These high alloying powders have a high hardness of the powder particles themselves, therefore a strong plastic processing, such as hot extrusion, must be given to make it into an alloy.

Embodiments

Alloy powders of compositions shown in Table 1 were manufactured by the air atomization process, then these powders were made into extrusion materials by hot extrusion at a temperature of 450°C. Properties of the obtained materials are shown in Table 2. Al-Si-Fe and Al-Si-Ni-Fe alloys manufactured by

the same method were also written for comparison. Alloys containing time-effect elements such as Cu or Mg were melted at 470°C for 2 hours and then cooled in water, and subsequently a 6 hour time-effect treatment was given at 170°C.

As is known from the table, the alloys with the time-effect hardening elements, such as Cu or Mg, added have high tensile strength at room temperature and also have higher abrasion resistance than the Al-Si-Fe-Ni alloy without Cu or Mg.

The alloys with transition elements, such as Cr, Zr, Co, Mo, and so on, added have an improved tensile strength at 300°C.

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Table 1 Alloy composition

		a								
b										
c										

* The composition of balance is substantially Al.
(Translator's note)

a. Composition

b. Present invention

c. Comparative material

Table 2 Material characteristics of alloys

			a		c	d		e		f
			b							
g										T6 treated material
										Extruded material
										T6 treated material
										Extruded material
h										Extruded material

- Abrasion rate 2.0 m/sec in abrasion test

(translator’s note)

a. Tensile strength (kg/mm^2)

b. Room temperature

c. Elongation % (room temperature)

d. Charpy impact value (kg≅m/cm^2)

e. Specific abrasion loss (× 10^{-7} mm^2/kg)

f. Remarks

g. Present invention

h. Comparative material

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As applications for these alloys, engine parts, connecting rods, pistons of automobiles that are heat-resistant and abrasion-resistant parts, vanes of compressors, and so on are given. The weight can be further lightened and the development of high-performance products may also become possible by using the invented aluminum alloys in these parts.

[Effects of the Invention]

As described above, the invented aluminum alloy has high tensile strength at high temperatures and is also excellent in impact resistance and abrasion resistance.

AMENDMENT (formal)

March 19, 1961 (Showa 61)

Michio UGA

Commissioner of the Patent Office

1. Indication of the case

Japanese Patent Application 60-222163

2. Title of the Invention

Heat-Resistant and Abrasion-Resistant Aluminum Alloy

3. Person Making Amendment

Relation to the casepatent applicant

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5. Date of correction order

January 28, 1986 (Showa 61)

6. Object of correction

Column of “Detailed Description of the Invention” in Specification

7. Correction contents

The following line is inserted between line 13 and line 14, page 2 in specification.

「III. Detailed Description of the Invention」